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THE EFFECTS OF PROLONGED SHOCK ON HABITUATION

by

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Abstract

The purpose of this study was to investigate the effects of subjecting animals to long periods of stress by observing subsequent responses to novel stimuli.

Three groups of male rats were used as subjects: the first group was shocked for varying lengths of time in boxes designed to minimize escape movements; the second group was similarly confined without shock. The third group was neither shocked nor confined and remained in ordinary rat cages for periods corresponding to the first two groups. After a rest period in ordinary cages each animal was then placed in an open field for an hour.

It was suggested that the long periods of shock would permanently weaken the effectiveness of the habituation mechanism in habituating the animal to subsequent arousal. Arousal was produced in this study by exposure to novel stimuli in the open field. The results provide only partial support for this prediction. Habituation, as measured by activity trends in the open field, may have even proceeded faster in the shocked animals, though the lack of a direct physiological measure of arousal makes any conclusion only tentative.

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The purpose of this study is to investigate the effects of prolonged arousal on subsequent exploratory behavior. Exposure to novel stimuli involves a process of habituation of arousal to the novel characteristics of the stimuli, which reduces exploratory behavior (Thompson, 1953). It is suggested that the process of habituation may be permanently delayed by submitting the organism to prolonged periods of repetitive noxious stimuli, thus weakening the inhibitory mechanisms of habituation and prolonging the occurrence of exploratory behavior when the animal is subsequently exposed to novel stimuli.

General Considerations

If a strong light is flashed on an amoeba, the organism reacts by moving away from the source of light. If the light is flashed on a second time, the response is now less intense. Finally, after many presentations of the light, the organism may not react to the light at all (Harrington & Leaming, 1900).

This sequence of events demonstrates what is perhaps the most pervasive form of behavior in animals. From amoeba to man, habituation, which is defined as a decrement of response with repeated stimulation, is one of the more fundamental properties of behavior. Habituation

has been called the simplest kind of learning, and the ubiquity of the phenomenon in almost every species through the phyla suggests that some of the basic principles of behavior may be revealed with further investigation.

In those animals possessing a synaptic nervous system, several forms of response decrement are distinguishable; they include sensory adaptation, nerve accommodation, neural fatigue, and "internal inhibition" (Pavlov, 1927) or "negative adaptation" (Humphrey, 1933). Habituation differs from both sensory adaptation and nerve accommodation primarily in its temporal characteristics; the response decrement may occur even when many minutes intervene between successive presentations of the stimulus and may persist for hours or even days. Adaptation also involves changes in receptor thresholds; e.g., eyes which are adapted to bright sunshine are not very effective when perceiving objects in a dim room. Changes in receptor thresholds are not involved in habituation, since stimuli of smaller intensities than the repeated stimulus may still elicit a response. Bartoshuk (1962) has demonstrated that habituation is not dependent on neural fatigue. His results show that a response which has become habituated to a specific stimulus can still be elicited by a novel stimulus; a fatigued receptor will fail to

respond not only to the repeated stimulus, but also to any novel stimuli of the same relative intensity (Sharpless & Jasper, 1956). What is commonly regarded today by psychologists as the phenomenon of experimental extinction was thought to be controlled by "internal inhibition" (Pavlov, 1927). Pavlov noted that the conditioned response gradually diminishes in strength when the conditioned stimulus is repeatedly presented without reinforcement by the unconditioned stimulus. Since the extinguished response shows partial recovery with rest, it would seem that some inhibitory process is involved.

Physiological aspects of habituation. Recent attempts to clearly define the mechanisms of habituation owe much to the now classic study by Moruzzi & Magoun (1949), who found that stimulation of the reticular formation did two things: first, it woke up a sleeping cat and alerted one already awake; second, it altered the EEG, producing the same changes in EEG which accompany waking or arousal. This finding firmly established the role of the reticular formation in the process of general alertness or arousal.

Further investigations (Lindsley, Schreiner, Knowles, & Magoun, 1950) brought out the fact that sensory impulses travelling towards the cerebral cortex could also be recorded in the reticular formation. This finding, coupled

with the fact that stimulation of the reticular formation causes activity in the cortex (Lindsley et al., 1950), demonstrated that the reticular formation is a separate pathway for sensory impulses travelling to the cortex. Lindsley et al. (1950) further showed that stimulation of the cortex evoked activity in the reticular formation, demonstrating that there is a closed loop between the cerebral cortex and the reticular formation.

Because of the importance of the reticular formation in maintaining and regulating the alertness of the organism, it is known as the reticular activating system (RAS). The reticular formation consists of a diffuse network of cells extending through the medial brain stem and parts of the hypothalamus, subthalamus, and ventromedial thalamus.

As a result of the studies cited above, and other findings, the previously vague physiological basis for habituation became much clearer. Both exteroceptive and proprioceptive sensory impulses have two means of influencing cortical activities; the sensory system conducts nervous impulses from the various sense organs to the thalamus and from there to the specific sensory areas of the cortex. Conduction in this case is fast, direct, and specific, enabling inputs in this system to serve as cues or "messages." Figure 1 illustrates schematically the various pathways which incoming

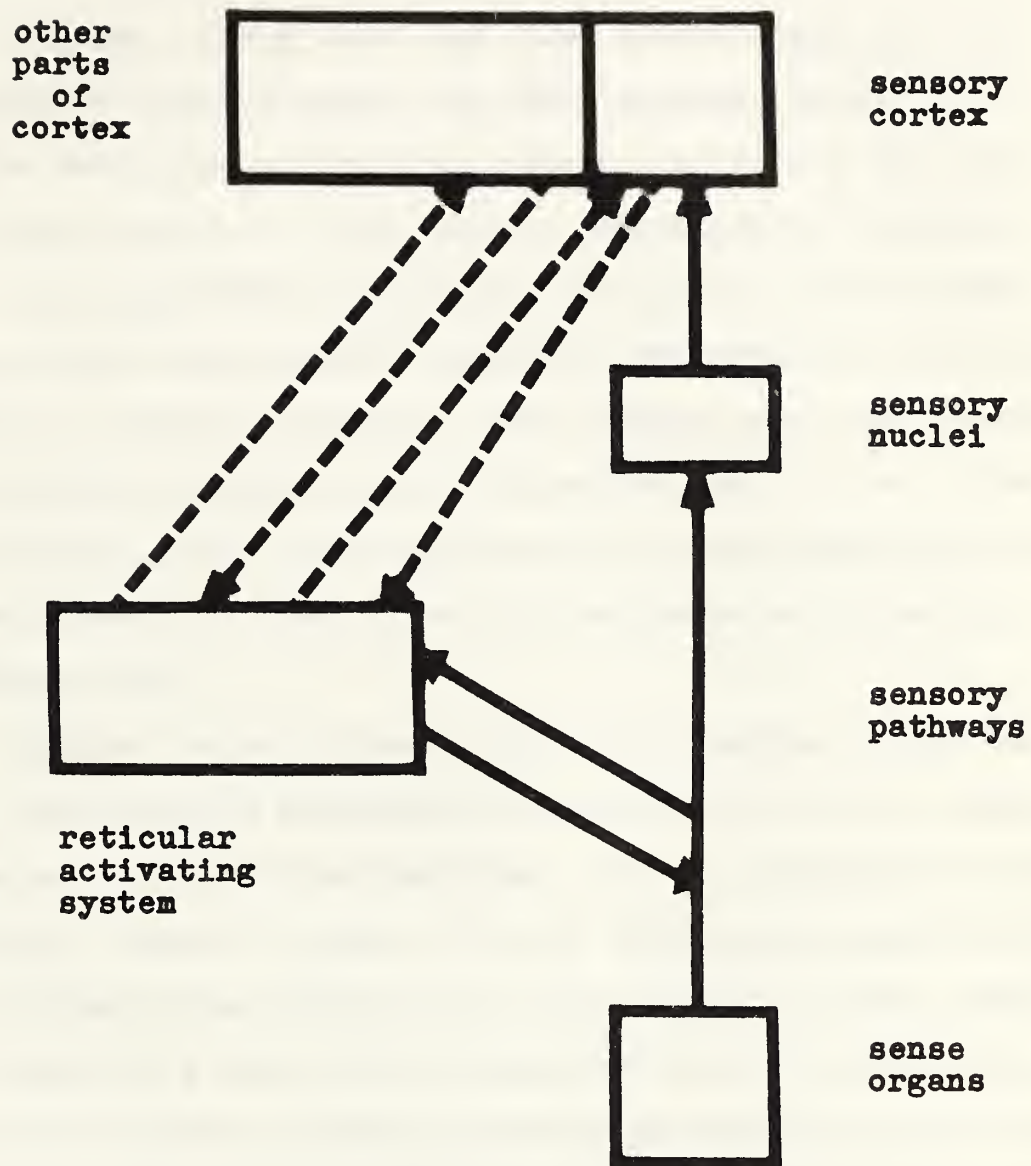


Fig. 1. Schematic diagram showing relation of the reticular activating system to sensory input and the cerebral cortex. (From: D. Bindra, Motivation. New York: Ronald, 1959, p. 255)

impulses may take and the relation of the RAS to the cerebral cortex.

Figure 1 shows that some time before reaching their respective sensory nuclei, sensory impulses branch off to the reticular activating system; impulses in this system are conducted over devious multisynaptic pathways and are transmitted diffusely to all parts of the cortex. Thus, every sense-organ stimulation initiates two different types of sensory processes. Some impulses are sent directly to specific cortical areas; others are sent to the cortex via the RAS, but these impulses are too diffusely spread to provide cues for specific action and serve an arousing function only.

Figure 1 also indicates that the function of the RAS is not restricted to modifying activity of the cortex; transmission of the afferent impulses from the receptors to the specific sensory areas of the cortex may also be subject to central neural impulses en route. Granit & Kaada (1952) and Hagbarth & Kerr (1954) demonstrated that stimulation of the RAS produced a strong reduction in the amplitude of the afferent potentials. Similar inhibitory influences upon the transmission of sensory impulses were also observed in the olfactory bulb (Kerr & Hagbarth, 1955) and the cochlear nucleus (Hernandez-Peon & Scherrer, 1955). Magoun (1958)

concluded that diffuse central influences thus seem generally capable of reducing afferent transmission at the first central sensory relay. The functional significance of this process becomes apparent when considering how an organism is gradually able to become accustomed to an irrelevant stimulus.

Arousal. In studying habituation, several reasons can be presented for giving particular attention to the arousal reaction. First, it is interesting not only for its own sake but also for the light it may throw on the principles governing the sensitivity of the reticular formation to repeated afferent stimulation. Second, the arousal reaction is known to habituate rapidly, a characteristic of great advantage in most investigations.

What is the arousal reaction? The state of arousal of an organism at any given time can be said to be manifested along a bipolar behavioral continuum, ranging from deep sleep or general anesthesia to panic or manic activity. The relative tenseness or calmness of the organism roughly delimit the characteristics of the organism that are described by the term arousal. Changes in these characteristics have been considered as variations in degree of "arousal" (Freeman, 1948), degree of "energy mobilization" (Duffy, 1951), and "activation" (Lindsley, 1951).

Davis, Buchwald, & Frankmann (1955), Sharpless & Jasper (1956) and Bartoshuk (1962) have shown that the presentation of a simple stimulus increases level of arousal, and the increase in arousal is roughly proportional to the intensity of the stimulus and is also a function of the novelty of the stimulus. Several studies (Freeman, 1940; Schlosberg, 1954; Stennet, 1957) have suggested that there is a relation between level of performance and level of arousal. The relation is an inverted U-shaped function: as the level of arousal remains low so does proficiency on a given task; as the level of arousal rises to a moderately high level, the task performance attains an optimum peak, and as arousal goes even higher task performance drops off.

The Problem

The possibility of a relationship between habituation and arousal was hinted at by Malmö (1957). In a review of the literature, Malmö pointed out that several studies (Malmö & Shagass, 1949; Malmö, Shagass, Belanger, & Smith, 1951) have shown that pathologically anxious patients are more reactive than "normals" under standard conditions of stimulation.

It has generally been assumed that higher levels of anxiety are produced by those stimuli which, through

learning, have acquired special meaning for the patient. However, Cameron (1944) has pointed out that chronic anxiety symptoms are elicited primarily by nearly everything in the environment which tends to increase arousal.

To account for the higher reactivity of pathologically anxious patients, Malmo (1957) noted that the reticular activating system inhibits continued arousal evoked by repeated exposure to novel stimuli. In those who are chronically anxious, Malmo suggests that this inhibitory mechanism becomes weakened, thus producing higher arousal levels in response to standard stimuli than those which occur in "normals." Malmo proposed that chronic anxiety be considered as a "disease of over-arousal," in which over-reactivity results from a weakening of inhibition brought about by submitting the reticular activating system to prolonged stress through extended and excessive arousal. If the RAS is maintained at a high level of activity for prolonged periods with stimuli of high-arousal potential, then it seems reasonable to assume that a critical change in the RAS will finally occur, and the organism will no longer be capable of habituation to subsequent arousal. More specifically, the following hypothesis is proposed: animals subjected to continuous or prolonged arousal will exhibit a relatively permanent loss of habituation of the

arousal reaction to novel stimuli.

The relationship between arousal and exposure to novel stimuli has been investigated by Hall (1941), Broadhurst (1957), and others (Sines, 1961; Candland & Campbell, 1962), using the open field situation. The assumption underlying this test is that an unfamiliar environment which is markedly different from the animals' normal habitat elicits an aroused state which produces an autonomic reaction resulting in overt responses of defecation and urination, accompanied by some degree of exploratory activity.

There is evidence to indicate that the amount of exploratory activity in the open field is related to the degree of arousal of the animal. Exploration appears to decrease as the arousal of the animal increases; for example, Montgomery & Monkman, (1955) found a decrease in exploratory behavior with animals which had been shocked while in the open field, compared to non-shocked animals. Similarly, Thompson & Higgins (1958) showed that when shocked animals were subsequently given a choice of exploring a new environment or returning to a familiar one, they not only preferred to return to the presumably less arousing familiar chamber, but their activity was also lower than non-shocked animals. However, it should be noted that both Montgomery & Monkman and Thompson & Higgins used relatively

short periods of prior arousal (20 sec. and 3 sec. of shock, respectively). Both these studies may be interpreted as demonstrating that short periods of arousal produced just prior to exposure to novel stimuli tends to interfere with subsequent arousal evoked by novel stimuli, thus reducing exploratory activity.

In order to determine how prolonged periods of arousal evoked by shock affect subsequent arousal provided by novel stimuli, animals were shocked in boxes designed to prevent escape from the shock, thus tending to maximize arousal. A second group was confined in identical boxes for corresponding periods without undergoing shock. A third group of rats remained in ordinary cages. Each animal was then placed in the open field. It was expected that if the ability of the animal to habituate had been damaged by prolonged arousal under repetitive shock, then the animal would not be capable of normal habituation to subsequent arousal evoked by novel stimuli.

Method

The prime consideration was to maintain the animal at a high level of arousal for a prolonged period. As Malmö (1957) pointed out, the precise method by which arousal is maintained is not of importance; what is required is a method which will keep the animal in a continued state of high physiological arousal. Furthermore, the method of producing the long periods of arousal must be compatible with the open field so that the arousal situation does not confound the results obtained in the open field. The use of the open field for presenting novel stimuli to the animal precluded the use of any methods to induce chronic arousal by deprivation or physical exertion. One of the prime measures in the open field is the activity of the animal, and this measure could be confounded by the effects of deprivation or exhaustion.

Many problems were posed however, by the selection of shock as the arousing stimulus. When using shock as a noxious stimulus, experimenters often neglect or ignore important parameters of electricity in reports of their studies. A pilot study was therefore carried out to determine at least an approximate shock setting which would be low enough to avoid an excessive number of deaths, and yet which would also be sufficiently high to ensure constant arousal.

It was originally intended to use a physiological measure

to obtain a valid estimate of arousal. The original intention was to continually shock animals for various periods after obtaining a basal heart rate. After returning to their home cages for a day, the animals would be placed in the open field for an hour and heart rate recordings would monitor the changes of arousal in the animal while in the open field. However, due to many difficult methodological problems, the heart rate measure was omitted from the study, and measures of activity, latency, defecation, and urination were used.

Subjects. Ninety-nine Sprague-Dawley male rats from a local supplier (N.A.T. Lab. Co.) served as subjects. Their weights ranged from 180 gm. to 230 gm. prior to the experiment, and each animal received minimum human contact as part of the raising procedures used by the supplier. During the experiment, the animals were only handled when transferring them from different apparatus. Food and water was made constantly available to the animals throughout the experiment except during the open field.

Design. The general design was of a 2 x 4 nature. Each of two groups, the experimental and control groups, was divided into four treatments. Each treatment represented various lengths of time in a small shock box, designed to prevent escape from the shock. The animals were confined in the boxes for intervals of 2 hr., 2 days, 10 days, and 30 days.

The upper limit of 30 days was selected largely on the basis of results obtained by Brady, Porter, Conrad, & Mason (1958) and Mahl (1950), who found that most monkeys and rats ulcerate after 20 to 30 days of shock. The other intervals were chosen in the hope of obtaining a roughly inverted-U distribution of habituation to the shock. Thus it was hoped that the 2 hr. and 2 day groups would exhibit increasing habituation to the noxious stimulus as measured by heart rate, while the 10 day and 30 day groups would have been subjected to the noxious stimulation long enough to set up the critical neural change and would therefore show a decrease in ability to habituate. No previous data was available on the choice of these periods, and the study became exploratory insofar as this point is concerned.

In addition to these eight treatment groups, the design also included a secondary control group which was quite separate from the main experimental and control groups. The secondary control group was a control condition for any effects which might accrue from living in the shock boxes.

The experimental and control groups were comprised of 44 animals each, all divided randomly among the four treatments. The remaining 11 animals were in the secondary control group.

Apparatus. The rats were shocked in specially constructed

boxes which, while allowing each animal to perform its physiological functions normally, permitted only horizontal movement and reduced vertical movements to a minimum. This type of shock box was used to minimize avoidance reactions and to maximize the arousal of each animal to the shock, which might be dissipated to some extent by avoidance movements. Bindra (1959) has noted that when an animal is prevented from engaging in an activity which it customarily performs in a given situation -- a frustration situation -- its level of arousal is likely to increase. The confinement boxes, as they shall now be called, were built in units of three so that each unit was comprised of three confinement boxes. An illustration of the apparatus is shown in Fig. 2. The outside dimensions of the confinement boxes were 7 in. long by 10 in. wide by 2 in. high (from bars to top).

The open field apparatus was similar to that used by Hall (1941) and Candland & Campbell (1962). The open field measured 7 ft. in diameter, and the walls were of unpainted corrugated galvanized metal about 30 in. high. A 200 watt bulb in a reflector illuminated the field. A Grason-Stadler noise generator supplied -20 db of white noise to the experimental room when the animals were undergoing shock and also when in the open field.

Activity in the open field was measured by a photocell



Fig. 2. A unit of three confinement boxes as used in this study. Food was delivered through the chute on the front of each box.

arrangement around the open field. Six Worner photocells were placed around the outside perimeter of the wall of the field, and beams of light entered the cells through 1 in. holes cut in the metal walls and covered by red acetate film. Light was transmitted to each photocell by a 100 watt bulb on the opposite side of the field. The field was thus divided into squares of approximately 18 in. Activity in the open field was recorded by a counter which was activated when an animal crossed a photocell beam. The counter was of the print-out type, enabling an interval timer to trip the print-out mechanism every three minutes. This arrangement provided a cumulative record of each animal's activity.

Procedure. After arrival at the laboratory, each animal was caged individually in ordinary rack cages for five days to permit familiarization with diet changes and the new environment. After five days, the animals were placed in the confinement boxes and selected randomly as control animals or experimental animals. The sole variable between the groups was that the experimental group received 15 volt, 60 cycle AC pulses varying randomly from 0.5 to 1.5 sec. in duration and delivered randomly once every minute, 24 hours a day. The shocks were delivered through a Variac variable step-down transformer to 1/8 in. brass rods 1/2 in. apart in the bottom of the confinement boxes. The shocks were timed by a micro-

switch which was activated by holes punched at appropriate intervals along a film-strip, the film moving past the switch at a set speed. The microswitch was connected to the secondary of the transformer.

After completing their length of treatment, the animals were removed from the confinement boxes and returned to their "home" cages for 24 hr.

At the end of this time, the animals were placed individually in the open field for 60 min. and measures of latency, activity, defecation, and urination were recorded.

The secondary control was submitted to the same procedure with the exception that they were placed in normal rack cages instead of the confinement cages for 30 days.

Results

Deaths. During the course of the experiment, 12 rats out of a total of 99 died. All the deaths occurred in the experimental group, indicating that shock was highly instrumental in producing the deaths. The probability that all the deaths occurred in the experimental group by chance was found to be less than 0.1% ($\chi^2 = 17.07$). No autopsies were carried out to determine the primary cause of death.

It is important to note that out of the 12 rats which died, eight were members of the 30 day experimental group. Since this reduced the n to three in this group, the results of the 30 day group were not included in the analysis of the data. It was felt that the high mortality rate destroyed the randomness of the sample, thus biasing the results; presumably only the stronger or perhaps less reactive rats survived in this group, and the remaining animals would not be a random sample of the population.

The remaining four deaths were distributed among the other groups; two occurred in the 2 hr. group, and the two day and 10 day groups accounted for one death each. Since two deaths occurred in the group with the shortest period of shock, it appears that the deaths were not an increasing function of days of shock and occurred randomly, at least up to and including the 10 day group. The occurrence of deaths, therefore, seriously biased only the

results of the 30 day group, which were subsequently not included in the analysis of the data.

The data obtained from two further animals was also excluded from the results, due to a malfunctioning of the open field recording apparatus. The malfunctionings occurred on two different occasions when running control animals from the 2 day and 10 day groups. The data omissions are thus distributed so as to reduce the n of two of the control groups by only one animal each.

Activity. Open field activity was recorded every 3 min. for 60 min., but for purposes of analysis the 3 min. recordings were grouped into four means, each representing 15 min. of activity.

The activity means of the 2 hr., 2 day, and 10 day control and experimental groups over the four 15 min. periods are shown in Fig. 3. The trends for all groups show a steady decrease in activity over the 60 min. period. The results also show that activity for the experimental groups appears to be less than the control groups after the initial 15 min. period in the open field, but the differences in activity between the experimental and control groups show a steady decline to zero for the rest of the hour.

A trend analysis was carried out to determine the significance of the differences in trends between groups.

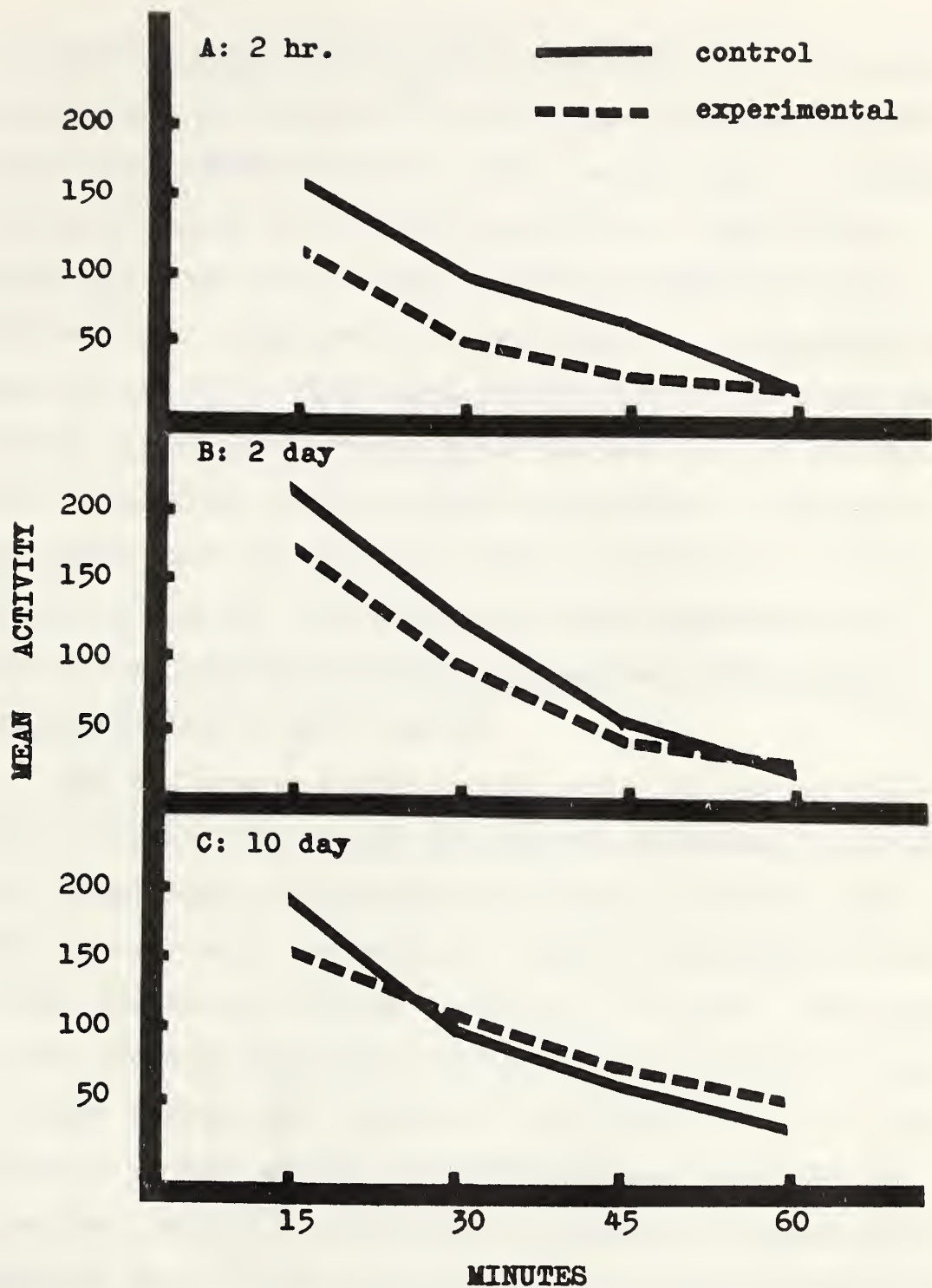


Fig. 3. Mean activity of (A) the 2 hr. group, (B) the 2 day group, and (C) the 10 day group during 60 min. in the open field over 15 min. intervals.

A procedure suggested by Grant (1956) was used for analyzing curves that result when the differences between intervals in the independent variable are in equal steps. A summary of the analysis is presented in Table 1. The analysis indicated that the over-all trend was significant both in its linear components and its quadratic components (see rows A1 and A2). This means simply that the over-all means varied significantly throughout the four 15 min. blocks, and the presence of the linear and quadratic components indicates that the over-all trend of activity is curvilinear; since the linear slope is also significant, it can be concluded that activity decreases curvilinearly throughout the 60 min. period.

The difference between group means is also significant, both when the means are grouped according to control and experimental conditions (see Table 1, row Ba), and also when grouped according to length of treatment (2 hr., 2 day, and 10 day groups; see Table 1, row Bb). The results of the trend analysis thus indicate that activity of the combined experimental groups is less than activity of the combined control groups. The means summed over the one hour test period for the various lengths of treatment are shown in Fig. 4, and the results of the trend analysis show that the activity of the 2 hr. group is less than the activity for both the 2 day and 10 day groups.

Table 1.

Summary of the analysis of the trends of open field activity.

Source of variation	df	Sum of squares	Mean square	Error term (row)	F
A. Over-all trend	(3)	(718848.9)	(239616.3)	E	(177.95)**
1. Linear	1	682873.2	682873.2	E.1	335.81**
2. Quadratic	1	33701.4	33701.4	E.2	26.73**
3. Cubic	1	2274.2	2274.2	E.3	3.05
B. Between Group Means	(5)	(72471.1)	(14494.2)	D	(3.13)*
a. Condition (C & E)	1	25051.2	25051.2	D	5.40*
b. Shock length	2	32043.9	16021.9	D	3.46*
c. Interaction	2	15376.0	7688.0	D	1.66
C. Between Group Trends	(15)	(38791.8)	(2586.1)	E	(1.92)*
1. Linear	(5)	(33910.1)	(6872.0)	E.1	(3.38)**
a. Condition (C & E)	1	29008.3	29008.3	E.1	14.27**
b. Shock length	2	4379.2	2189.6	E.1	1.08
c. Interaction	2	522.6	261.3	E.1	0.13
2. Quadratic	(5)	(3172.0)	(616.4)	E.2	(0.49)
a. Condition (C & E)	1	236.0	236.0	E.2	0.19
b. Shock length	2	400.9	200.4	E.2	0.16
c. Interaction	2	2535.1	1267.5	E.2	1.01
3. Cubic	(5)	(1709.5)	(341.9)	E.3	0.46
a. Condition (C & E)	1	720.8	720.8	E.3	0.97
b. Shock length	2	607.5	303.7	E.3	0.41
c. Interaction	2	381.2	190.6	E.3	0.26
D. Between Individual Means	54	250385.0	4636.7	E	3.44**
E. Between Ind. Trends	(162)	(218136.8)	(1346.5)		
1. Linear	54	109811.6	2033.5		
2. Quadratic	54	68098.1	1261.0		
3. Cubic	54	40227.4	744.9		
Total	239	1298633.6			

* p < .05

** p < .01

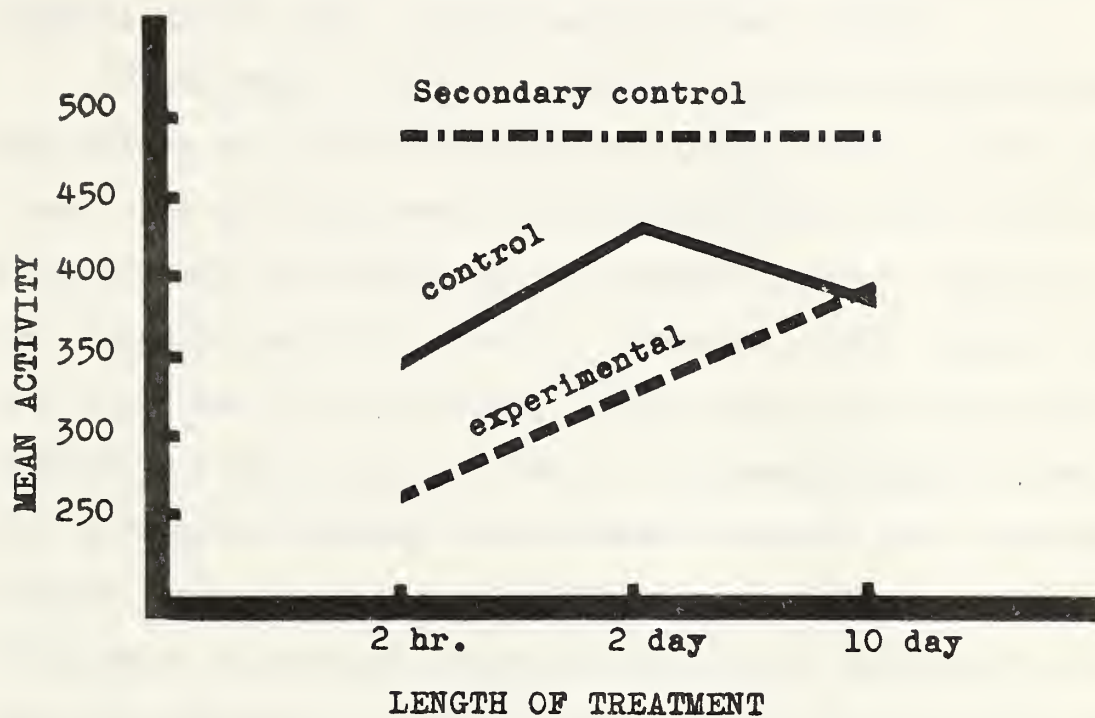


Fig. 4. Mean activity as related to length of treatment.

It was also shown by the analysis that the slopes of the trends are significantly different for the control and experimental groups (see Table 1, row C1a). The data in Fig. 3 indicates that the decrease in activity is steeper for the control groups than for the experimental groups.

To determine if being confined in the boxes was having any effect on the activity of the animals while in the open field, the activity mean for the secondary control group was compared with the means of the control groups; Dunnett's test for comparisons with a control (Edwards, 1960) showed that the 2 hr. and 10 day control groups were less active than the secondary control ($p < .01$ and $p < .05$ respectively). The over-all difference between the secondary control and the combined control groups was also significant ($t = 2.04$; $p < .05$). The difference in over-all means seems largely accounted for by the differences of the 2 hr. and 10 day control groups (see Fig. 4).

Latency. The times required by each group of animals to move across the first square in the open field are summarized in Table 2. The differences were tested with t tests and were not significantly different. The values of t ranged from 0.53 to 1.29.

Defecation and urination. The means for defecation and urination are shown in Table 3. After analysis with t tests, the differences were not found to be significantly different

Table 2.

Mean latencies to leave first square in
the open field.

Condition	Length of treatment		
	2 hr.	2 day	10 day
Experimental	6.30	4.89	7.01
Control	8.13	6.29	7.41
Sec. Control	3.64		

Table 3.

Combined mean scores of defecation and
urination in the open field.

Condition	Length of treatment		
	2 hr.	2 day	10 day
Experimental	2.2	5.0	5.0
Control	3.6	5.1	6.5
Sec. Control	3.7		

either when the measures were considered individually or when the two measures were combined. When the measures were combined, the values of t ranged from 0.78 to 1.74.

Additional findings. An interesting trend was noticed in the data for the first 21 min. of activity in the open field. This trend is shown in Fig. 5, which shows the original ungrouped 3 min. means of activity. The curves show a trend in activity which is not apparent when the data is grouped into four 15 min. blocks of activity. Both control and experimental groups appear to show nearly equal amounts of activity up to the first 3 min.; after the first 3 min. period however, divergent trends seem to appear. Activity of the experimental groups decreases much faster than the activity of the control groups; the control groups even show a slight rise in activity for a short period of time before decreasing. No analysis was carried out on these trends because of the ad hoc nature of their selection, but the trends are nevertheless interesting to observe because of the initial steep drop in activity which is seen in the experimental group. It is quite likely that this steep drop in the experimental group accounts for the initial lower level of activity during the first 15 min. observed in Fig. 3. It appears that the grouping of the 3 min. means of activity into 15 min. blocks obscured these changes in activity mentioned above;

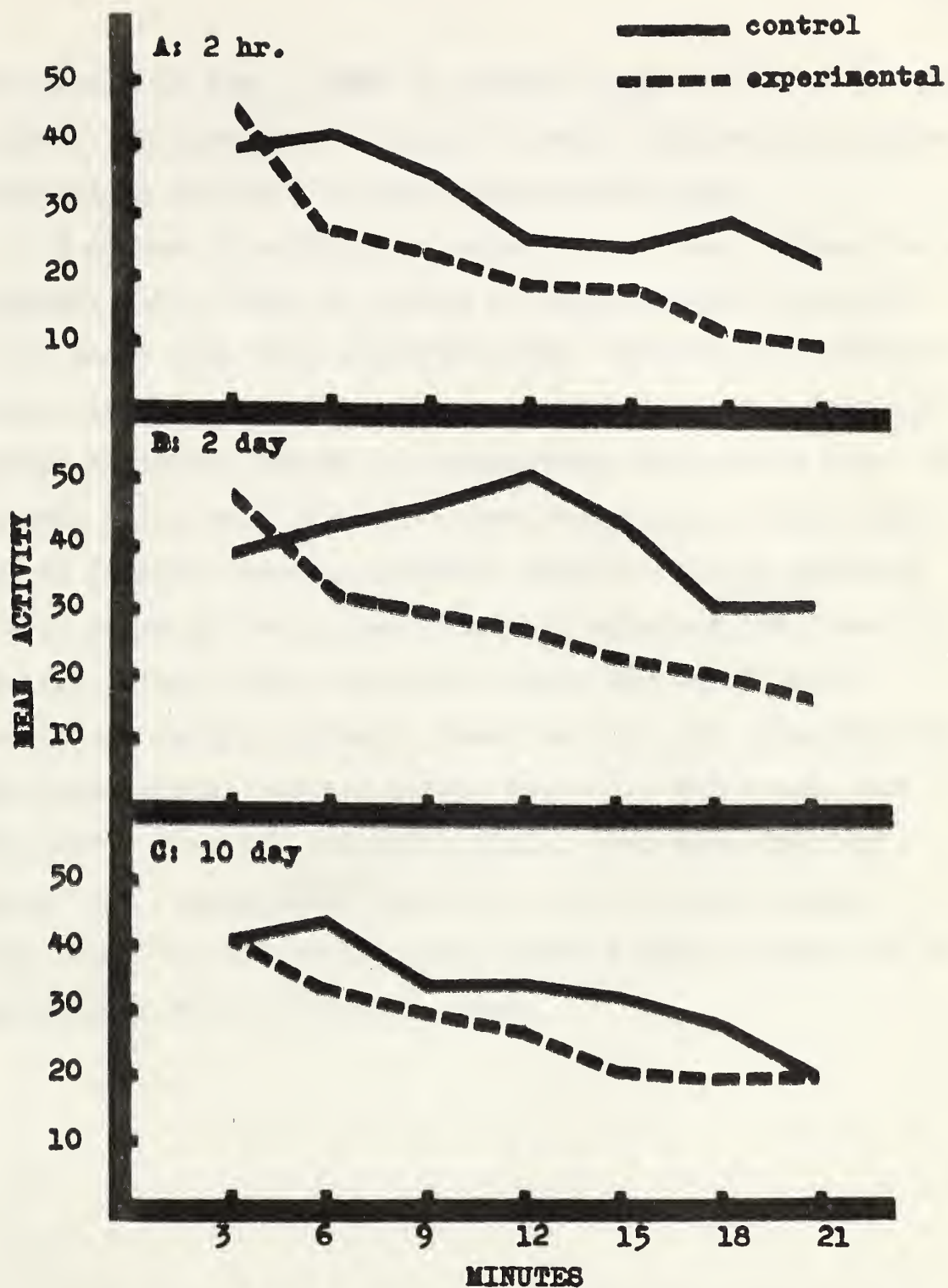


Fig. 5. Mean activity of (A) the 2 hr. group, (B) the 2 day group, and (C) the 10 day group during the initial 21 min. in the open field over 3 min. intervals.

the curves in Fig. 3 show no initial equal levels of activity between experimental and control groups followed by a steep decrease in activity of the experimental group.

A common observation of behavior was made during the experiment which might be called a "displacement" activity. It is known that when prevented from engaging in a particular activity, an individual may engage in a completely different activity. Though no quantitative record was kept, the animals which were prevented from escaping the shock indulged in furious chewing activity, usually chewing anything within reach of the animal's mouth (including, at least in the preliminary work, electrode leads for heart rate). Though the control animals chewed as well, it appeared that the experimental animals chewed much more vigorously and frequently than the control animals, even when food and water was constantly available. All the dead animals were found to have their teeth locked tightly around one of the bars in the floor of the cage.

Discussion

The major findings of this study were:

- 1) Over-all activity in the open field showed a declining trend; moreover, the experimental group trend decreased less sharply than the control group trend.
- 2) Mean total activity was less in the experimental group than in the control group.
- 3) The control groups showed less activity than the secondary control (non-confined) group.
- 4) Almost 12% of the Ss died; all were members of the experimental group.
- 5) No significant findings were shown with latency or elimination measures.

The evidence from this study seems to provide only partial support for Malmo's position. The occurrence of a flatter trend of activity in the experimental group compared to the control group offers only apparent support for the hypothesis. First consideration of this data indicates that the habituation of the experimental groups, as measured by exploratory activity, is not proceeding in a normal fashion. The slower rate of decrease of activity appears to indicate that the process of habituation is being delayed in the experimental Ss, according to expectations.

Closer inspection of the results reveals however, that this interpretation should be made only tentatively. The fact

that the trends of activity show different rates of decline is not fully sufficient to support the expectation that the animals would exhibit a "relatively permanent loss of habituation." It is true that the slopes of the activity trends do differ; however, this alone does not provide satisfactory evidence in this study that the rates of habituation of arousal are different or that there is a permanent loss of habituation.

The evidence is not sufficient to support the hypothesis because the results in Fig. 3 show that after an initial decrease in activity, the activity of the experimental Ss eventually equalled that of the control animals after one hour in the open field. The hypothesis predicts a permanent loss of habituation, and this loss should therefore be reflected by a much flatter decrease of activity for the experimental Ss than was observed in this study. The differences in slopes of the trends should have been more widely separated if the hypothesis had been borne out; in fact, the curves should have intersected rather than converged. The convergence of the two curves after one hour indicates that the experimental animals did most of their habituating to the novel stimuli from a lower level than the control group. It appears that habituation then proceeded so as to bring the experimental animals' activity (and presumably arousal)

eventually to the same level as that of the control animals. If habituation had been permanently destroyed in the shocked animals, then the activity trend should have shown a flatter rate of decrease than was obtained in this study, resulting in a curve that would intersect with the trend of the control animals.

It is evident from the data in Fig. 3 that the differences in the slopes of the trends can be accounted for by the initial differences in activity. It was pointed out earlier however, that the initial differences in activity were obscured by combining the means of activity obtained over 3 min. intervals into one mean representing 15 min. blocks of activity. A more accurate indication of the initial differences in activity can be seen in Fig. 5, which shows the first 21 min. of activity over 3 min. intervals. Inspection of this data raises the possibility that the prolonged shock may have served to produce faster habituation to the open field stimuli than that obtained in the control animals. It can be reasoned that exposure to noxious stimuli in one situation may facilitate habituation to arousing stimuli in a second situation. The observations of the changes in activity in Fig. 5 furnish some evidence for this line of reasoning. Experimental group activity in these curves showed that the experimental groups did not start at a lower level of activity,

but actually were nearly equal; furthermore, the curves indicate that the experimental groups rapidly "habituated" to a lower level of activity (within 6 min.) so that the mean representing the first 15 min. block of activity (see Fig. 3) showed over-all lower responding. The possibility that habituation proceeded faster in the experimental groups is also suggested by slight to moderate increases in activity of the control groups before starting to decrease, while the experimental groups started decreasing almost immediately (see Fig. 5). This trend is directly contradictory to the hypothesis. Though the conclusions drawn from these figures were not submitted to statistical analysis because of the ad hoc selection of these time periods, these suggestions nevertheless provide an alternative explanation which should be thoroughly investigated before being discarded. Some experimental support for this explanation is furnished by Sines (1961) who found that shocked rats responded not only with less activity in the open field, but also with a slower heart rate than control animals 22.5 hr. after immobilization in a plaster cast; there were no significant differences in heart rate previous to the 22 hr. mark. It appears from these results that the shocked animals adjusted faster to the frustrating situation than the non-shocked animals did.

Prolonged shock clearly had an effect on mean total

activity for the experimental and control groups (see Fig. 4), and this fact further supports previous findings (Montgomery & Monkman, 1955; Thompson & Higgins, 1958) that shocked animals display reduced exploratory behavior.

It is of prime importance to remember that the major measure in this study was exploratory behavior, which was used only as a behavioral index of arousal. Without a direct physiological measure of arousal, three explanations of the trends of activity are possible.

The first logical possibility is that the experimental animals were not maintained in a chronic state of arousal. In replying to this possibility, the occurrence of "displacement" chewing and frequent deaths attests to the fact that the animals were undergoing some form of stress, although the absence of direct physiological measures of arousal tends to make this only a tentative reply.

The second explanation has already been suggested, and it rests on the assumption that the amount of exploratory activity is directly proportional to the degree of arousal. More specifically, it is assumed in the second explanation that as arousal increases, exploratory activity decreases. The results of this study can therefore be interpreted as showing that the shocked rats, with decreased activity, were more aroused during the initial periods in the open field, but

did not suffer a permanent loss of habituation. The assumption underlying this possibility must remain tenuous however; no empirical relationship between degree of physiological arousal and exploratory behavior has been reported in the literature.

The lack of evidence on the relationship between arousal and activity raises a third logical explanation of the results. If the monotonic relationship between arousal and activity has not been clearly established, then the decrease in activity of the experimental groups may be due to two possibilities: 1) the prolonged shock may have weakened habituation according to expectations, resulting in a state of arousal so high that any exploratory behavior may have been inhibited; 2) the prolonged shock may have adapted the animal so as to reduce subsequent arousal to novel stimuli to a minimum, thus resulting in little exploratory activity. Again it must be emphasized that these explanations are only tentative in the absence of a direct measure of arousal.

The effects of confinement were also found to be an important variable. The fact that the non-confined rats were more active than the confined (non-shocked) animals rules out the assumption that the differences between experimental and control groups were produced by shock alone. Confinement appears to exert a considerable influence on behavior in a novel situation; however, both shock and confinement acted

jointly to produce the decreased activity in the experimental group.

Though the effect of confinement is an important one, whether it was the physically debilitating effects of confinement or the psychological stress (or both) which produced the decreased activity cannot be definitely stated from the results of this study; several facts however, point to the view that psychological stress was the main agent. First, all animals received 24 hr. of rest in normal rat cages prior to the open field test. In preliminary work, this period was found to be sufficient for each animal to groom and recover from stiffness acquired during confinement. Second, the animals which were confined for only 2 hr. showed a significant decrease in activity (see Fig. 4). The physical effects of 2 hr. of confinement could not have been very extensive.

The absence of differences in defecation and urination can probably be accounted for by the fact that the defecation and urination was observed only after the end of 60 min. in the open field. Since the widest differences in activity were observed in the initial periods, it may well be that any differences in defecation and urination during the initial periods were obliterated by further defecation and urination throughout the remaining period of time in the open field. The absence of a difference in amount of defecation is contra-

dictory to the findings reported by Broadhurst (1957), but the difference in findings can be attributed to different experimental conditions (e.g., length of shock periods, noise level in the open field, etc.).

The high number of deaths in this study, all of which were in the experimental group, indicates that shock was highly instrumental in producing the deaths. Since no physiological inspection of the stomachs was made, the actual cause of death must remain open to question. Brady et al. (1958) found that 75% of his experimental monkeys died of extensive gastrointestinal ulcers after pressing a key to stop an unavoidable shock. Mahl (1949) also found a higher concentration of HCl in dogs' stomachs after unavoidable shock. If the animals in this study died of ulceration, then this appears to conflict with Brady's results; of his control animals (immobilized and subjected to shock whenever the "executive" monkey did not press the key), none showed any sign of lesions after subsequent autopsy. This finding is in opposition with the number of deaths encountered in the experimental rats in this study. The experimental rats received treatment very similar to Brady's control monkeys, and yet there appears to be a wide difference in the results. One explanation could be made which would reconcile the differences; Brady's executive monkeys missed pressing the key

(subsequently shocking both executive and control animals) only infrequently, and it is possible that the control monkeys in fact received very little shock compared to the experimental rats of this study.

Summary and Conclusions

To determine if prolonged arousal would produce a weakening of the habituation process to subsequent arousing stimuli, a group of rats was shocked for long periods of time in cages designed to restrict avoidance movements. A second group was similarly confined without undergoing shock. A third group was neither shocked nor confined, but remained in ordinary cages. After a period of rest, each animal was then placed in an open field for an hour to observe habituation to arousing novel stimuli, as measured by exploratory activity. In addition to activity, measures of latency, defecation, and urination were recorded.

The results did not confirm the expectation that habituation, as measured by activity, would be permanently delayed due to a weakening of the habituation mechanism to arousing stimuli. The shocked animals showed a flatter rate of decrease of activity than the non-shocked animals, but since the two trends converged after an hour, it was felt that this only showed that habituation proceeded at a different rate for the two groups; the hypothesis however, predicted a permanent loss of habituation. Moreover, closer inspection of initial activity in the open field revealed the possibility that habituation may have proceeded at a faster rate in the shocked animals,

contrary to expectations. In the absence of physiological measures of arousal, this conclusion can only be drawn tentatively.

Confinement in the small shock boxes was also found to decrease activity in the open field, though no differences were found in latency, defecation, or urination. Since a significant number of animals died in the experimental group, extended shock appeared to be an effective form of stress, though the exact cause of death was undetermined.

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APPENDIX A

Summary of activity in the open field.

Control				Experimental		
Min.	2 hr.	2 day	10 day	2 hr.	2 day	10 day
3	39.4	38.8	42.6	45.3	46.6	40.2
6	40.2	43.0	43.2	25.2	32.4	36.7
9	36.5	44.7	35.3	24.3	29.7	33.6
12	25.0	50.3	35.3	20.4	27.3	28.5
15	25.4	41.4	34.6	21.9	23.8	18.9
18	32.0	27.0	29.7	12.7	22.6	22.1
21	21.5	30.2	20.5	13.7	17.5	20.3
24	19.0	30.5	17.1	8.3	19.8	17.8
27	13.5	18.8	18.7	11.7	16.2	18.9
30	11.5	23.1	12.5	8.3	9.3	22.9
33	7.4	15.3	14.5	3.8	12.4	20.1
36	13.3	11.1	8.8	4.8	11.0	22.4
39	10.1	9.5	15.0	2.9	11.4	11.8
42	10.0	13.3	9.7	10.0	11.7	12.7
45	5.6	13.3	12.1	6.0	9.7	12.9
48	4.3	5.3	7.4	4.2	8.8	9.6
51	0.4	7.8	7.2	2.3	5.0	12.6
54	3.5	5.3	4.3	1.6	6.3	9.2
57	3.5	4.1	3.8	2.2	8.1	6.4
60	3.2	3.6	5.7	4.2	1.6	5.9
Total	325.2	436.4	378.0	234.8	332.1	383.5
N	11	10	10	9	10	10

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